(Pre-) Aerosol, Clouds and ocean Ecosystem (PACE) 2012 Pre-work

MDL: May 14-18, 2012

Agenda

- Program Context
- Mission Description
- Science Context
- Observation Geometry
- Key Mission Requirements
- PACE System Architecture
- Instrument Accommodation
- Concept Of Operations (CONOPS)
- Key Questions & Trades

References/Resources

- This Presentation
- CAD Model for OCE2 Instrument Available from IDL.
- PACE/OCE2 IDL Report
- “Instrumental concept and performances of the POLDER instrument”, SPIE Vol. 2572/79.
- Email: Jerome Riedi, “Additional 3MI Questions”, May 14, 2012.

PACE Program Context

- The PACE mission will make global ocean color measurements to provide extended data records on ocean ecology and global biogeochemistry (e.g., carbon cycle) along with polarimetry measurements to provide extended data records on clouds and aerosols.

- The PACE Science Definition Team (SDT) is chartered to provide a Design Reference Matrix (DRM)
  - Describes preliminary investigation approach for the PACE prime science mission, including expected scientific impact of a representative set of proposed strawman investigations

- A small Engineering Team (ET) was formed to provide engineering and technical information to support the SDT activities.
  - The ET is chartered out of the Earth Systematic Missions (ESM) Program Office, and include CS representatives from the Goddard Space Flight Center
  - Planned activities: Optical Design Laboratory Studies, Instrument Design Studies, and a Mission Design Study

PACE Program Context (cont'd)

- NASA HQ will own the studies
  - Firewall requirements during the SDT activity period to preserve fair competition
    - Conflict of Interest Form in place
    - The SDT activities end and team disbands ~ August 2012

- PACE Website: http://decadal.gsfc.nasa.gov/PACE.html

PACE Program Context (Cont'd)

- Ground Rules
  - Everything the ET produces will be made public, therefore:
    - *No* proprietary intellectual content
    - *No* use of competition sensitive content
    - *No* use of proprietary labor rates
- Engineering Team Members
  - Angela Mason, PACE/Decadal Survey Tier II Mission Manager, Code 420
  - Chi Wu, Decadal Survey Missions Systems Engineer**,** Code 420
  - Richard (Rick) Wesenberg, Senior MSE, Code 592
  - Jay Smith, Chief Engineer for Instrument Systems, Code 550

Mission Description (Cont'd)

- **Mission name**: (Pre-) Aerosol, Clouds and ocean Ecosystem (PACE)
- **Allowable Mission Cost**: Not specified.
- **Required Mission Lifetime**: 3 years
- **Desired Mission Lifetime**: 5 years
- **Mission Class:** *C*
- **Preferred Launch Vehicle**: Not specified
- **Mission Schedule/Lifecycle**:
  - Phase A start: 6/2013;
  - Phase B start 6/2014;
  - Mission PDR 6/2015;
  - Mission CDR 9/2016;
  - Observatory I&T start 5/2018;
  - Instrument Delivery 6/2018;
  - Ship to launch site 2/2019;
  - Launch preparation ends 4/2019;
  - 6 months Observatory slack 4/2019 – 10/2019;
  - LRD 10/2019.

Mission Description (Cont'd)

- **Spacecraft Build**: Commercial
- **Number of Instruments**: 2: OCE2 and Polarimeter
- **Special technologies**: None.
- **Ground Communications:**
  - Real time Broadcast (X band) Option
  - 2.4 m dia ground antenna, G/t ~ 22.5 dB/kT
- **OCE Concept:**
  - OCE2 concept has been through IDL
  - OCE3 concept is scheduled for IDL the week of June 11
  - OCE (without a "2") refers to either OCE2 or OCE3

PACE Science Context

- PACE science objectives include observations of
  - the broad open ocean,
  - atmosphere cloud and aerosol observations,
  - coastal estuaries.
- Success of PACE science relies on:
  - OCE measurement requirements that exceed those of heritage sensors particularly in terms of spectral range and resolution;
  - a rigorous calibration/validation program; vicarious (*in situ*) calibration
  - repeated data reprocessing of the mission data.
- Science Operations Center/Science Data Center

OCE Observation Geometry

- Sun-synchronous polar, noon (11am – 1:00pm, Trade study for 1:30pm) equatorial crossing time because
  - provides high illumination intensities for accurate retrievals from the relatively dark ocean,
  - minimizes atmospheric path lengths for improved atmospheric corrections,
  - minimizes the range of scattering angles for simplification of atmospheric corrections and surface bidirectional reflectance effects,
  - maximizes repeat observations of high latitudes to improve probabilities of viewing cloud-free scenes each day and
  - maximizes coverage of the entire Earth in the shortest amount of time.
- Noon descending preferred
- ~700 km altitude is preferred.
- Maintain to within ±10 minutes to better support atmospheric correction
- No orbit repeatability requirement

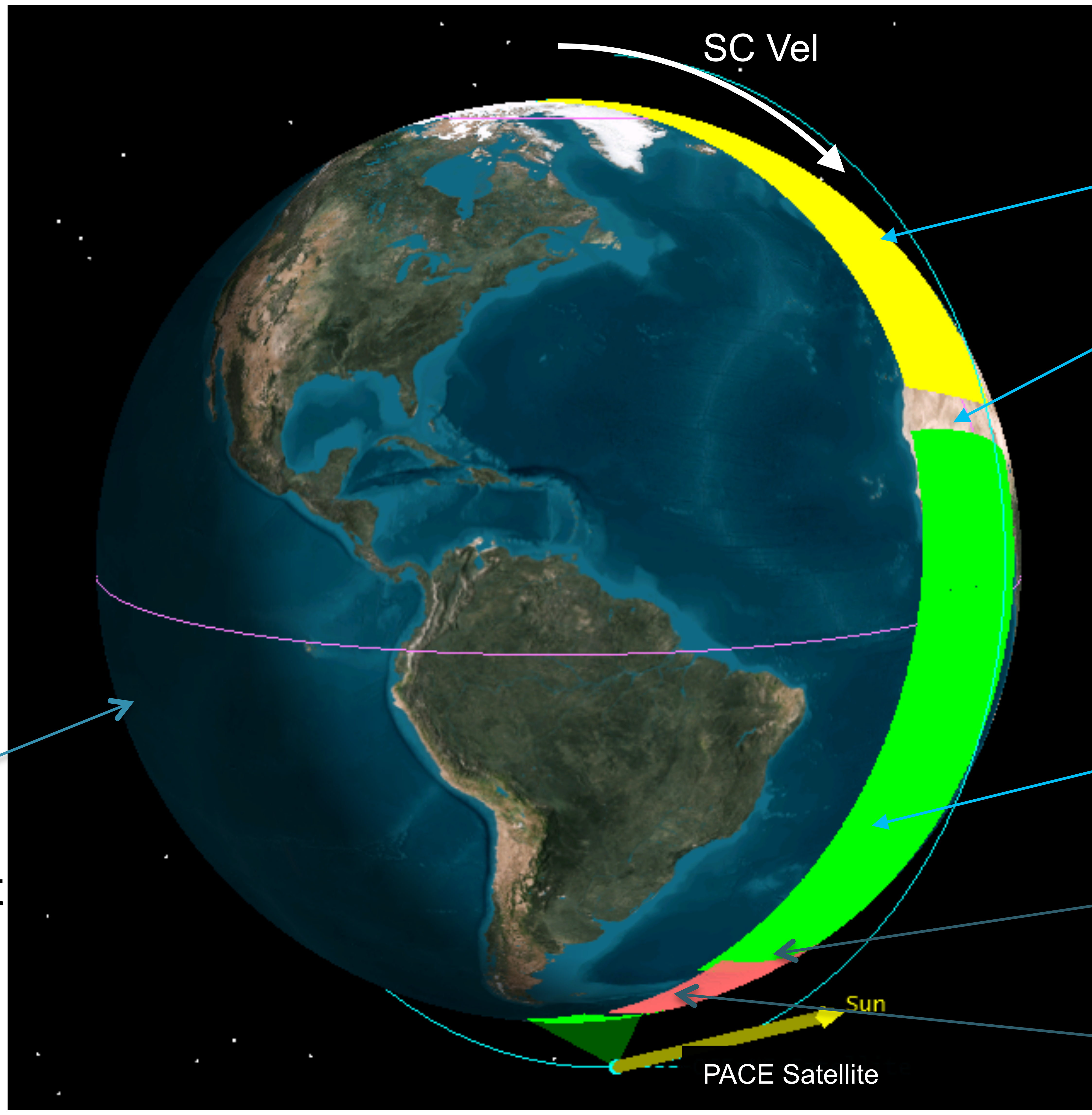
OCE Observation Geometry (Cont’d)

- Orbit
  - 2-day global coverage to solar zenith ≤ 85^o
  - Solar calibration *without* SC maneuver
- Attitude
  - Sun glint mitigation, +/- 20^o tilt along track,
- Spatial
  - Global coverage with a minimum spatial resolution of 1 km^2 (±0.1 km) along-track *tilted*
  - Keep data during tilt slews when sunlit but flag

Polarimeter Observation Geometry

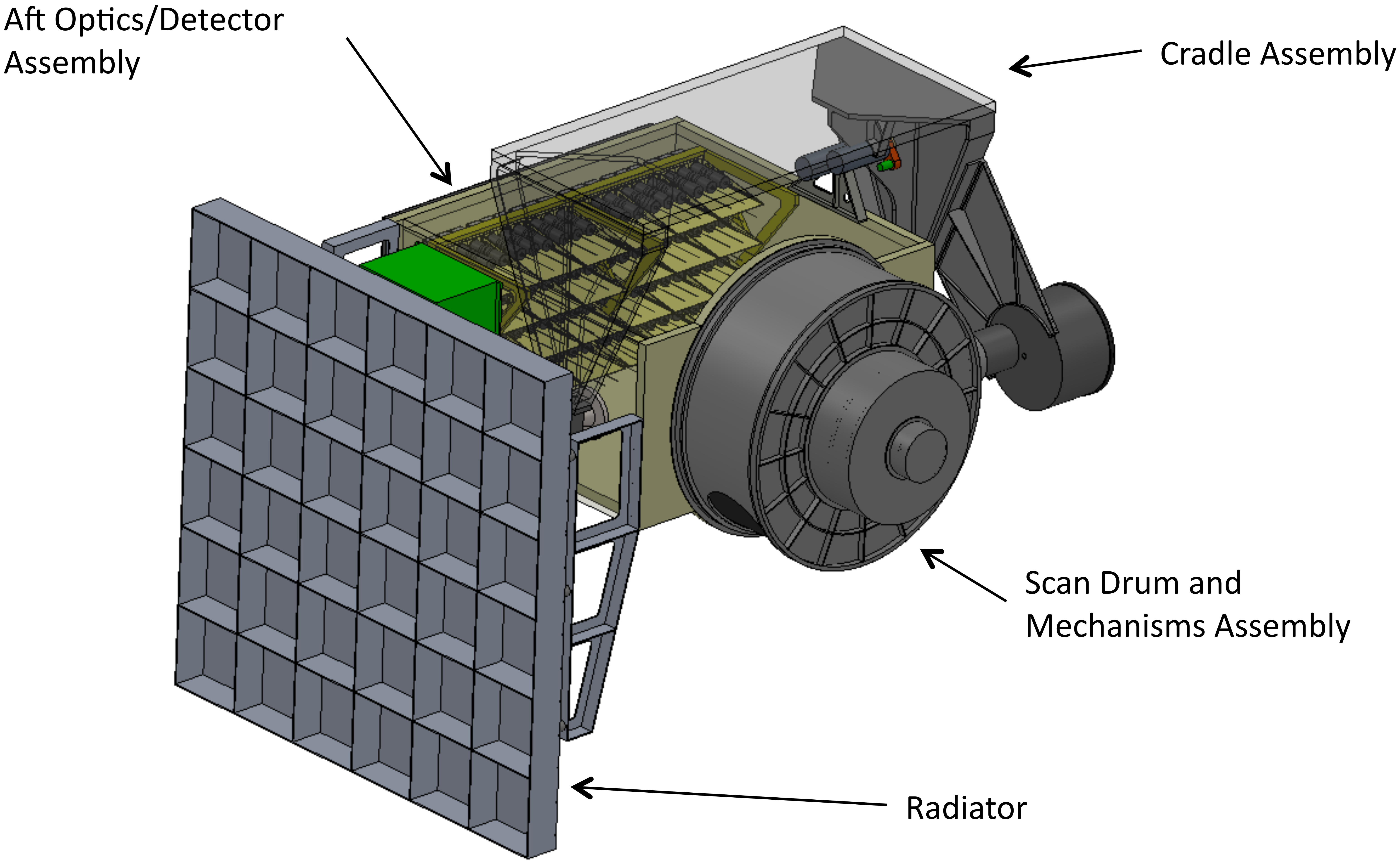
- Orbit
  - 2-day global coverage
- Altitude
  - OCE: ~ 700 km preferred
  - Polarimeter: 700-800 km preferred

OCE Forward and Aft Scans Switched at Sun Zenith

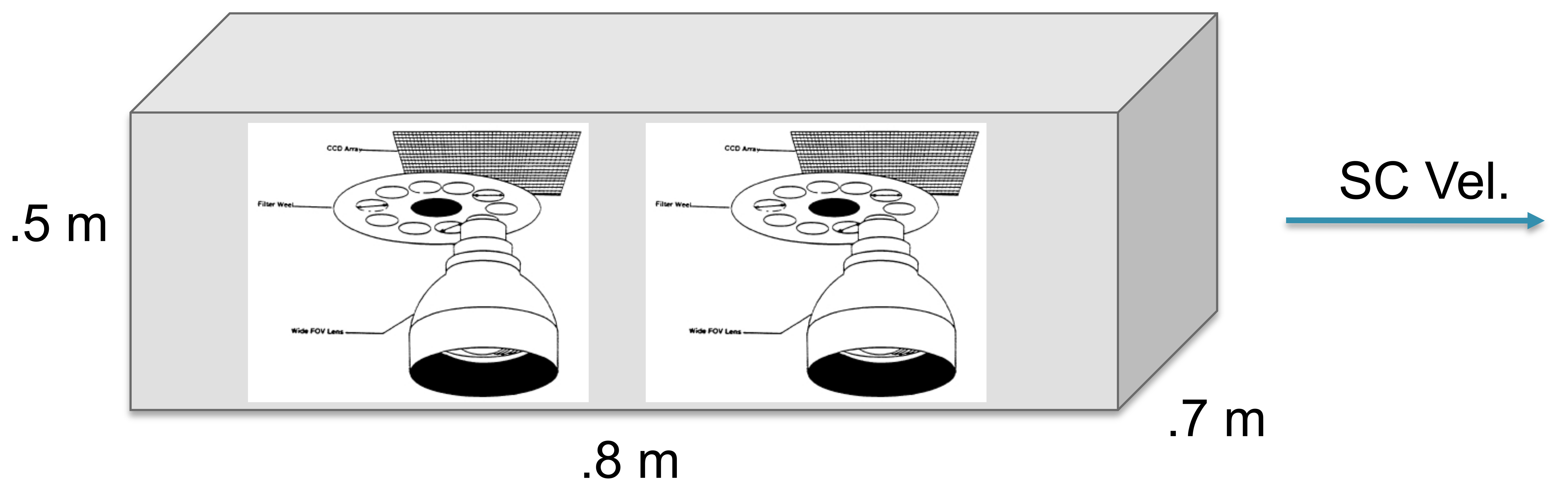


OCE Forward and Aft Scans, One at a Time, Just Past Sun Zenith Switchover

OCE2 Packaging Overview

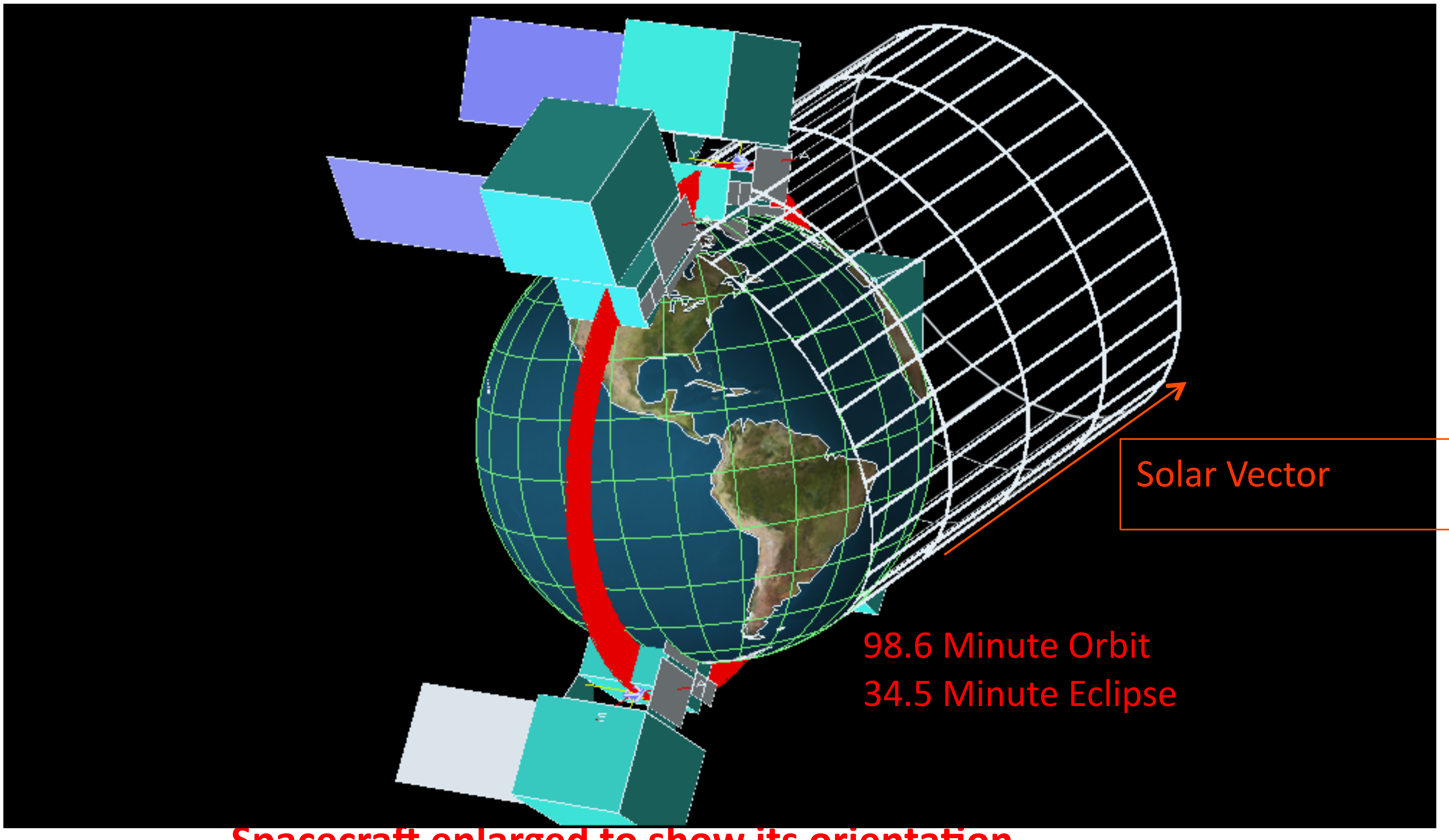


Polarimeter Packaging Overview



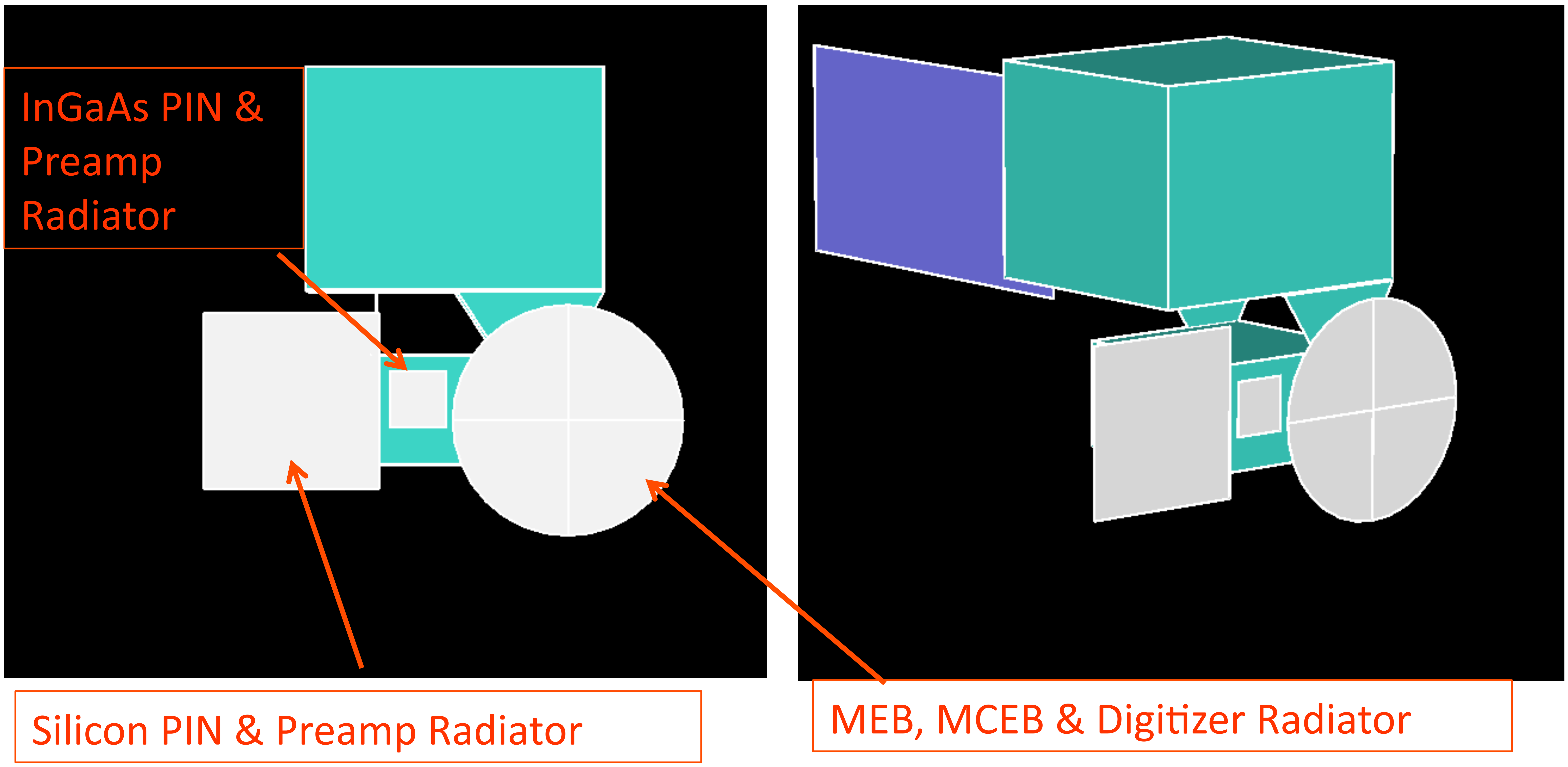
OCE2 Thermal Model

1100 Equatorial Crossing, -17˚ Beta

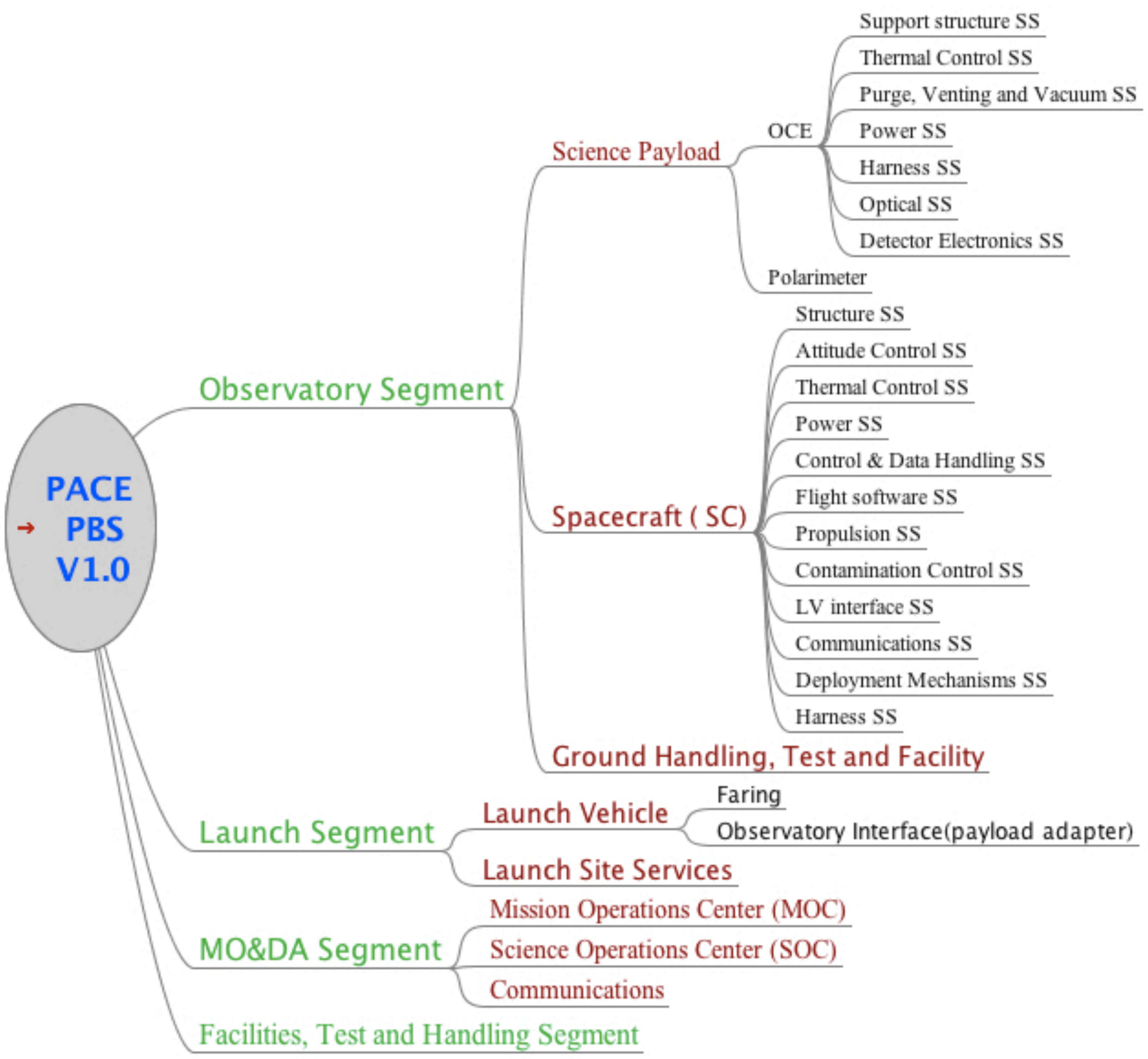


Spacecraft enlarged to show its orientation

OCE2 Radiator Size Predictions



PACE System Architecture



Anything missing?

Instrument Accommodation

- **Mass**
  - OCE2 CBE: 301 kg (1 assy)
  - Polarimeter CBE: 60 kg (2 assy)
- ***Power***
  - *OCE2 CBE: 515 W operating., 648W pk during spinup*
  - *OCE2 Survival Heater Power CBE: 244 W avg., 349 W pk*
  - *Polarimeter CBE: 85W=70 W imaging + 15W thermal, 30W=15W non-imaging + 15W thermal, survival power=30W, 100 W pk*
- **Data Rate**
  - OCE2: 10 Mbps (2:1 compression) , 30 Gbit/orbit (see following slide)
  - Polarimeter: 2.2 Mbps (3:1 compression), 6.6 Gbits/orbit
  - SC keeps only data where solar zenith ≤ 85°
- ***Volume***
  - OCE2: See Cad Model
  - Polarimeter: .8m x .7 m x .5m
- **Pointing Knowledge & Control**
  - OCE2: 25.4 arcsec (see following slide)
  - Polarimeter: <.25° (900 arcsec)

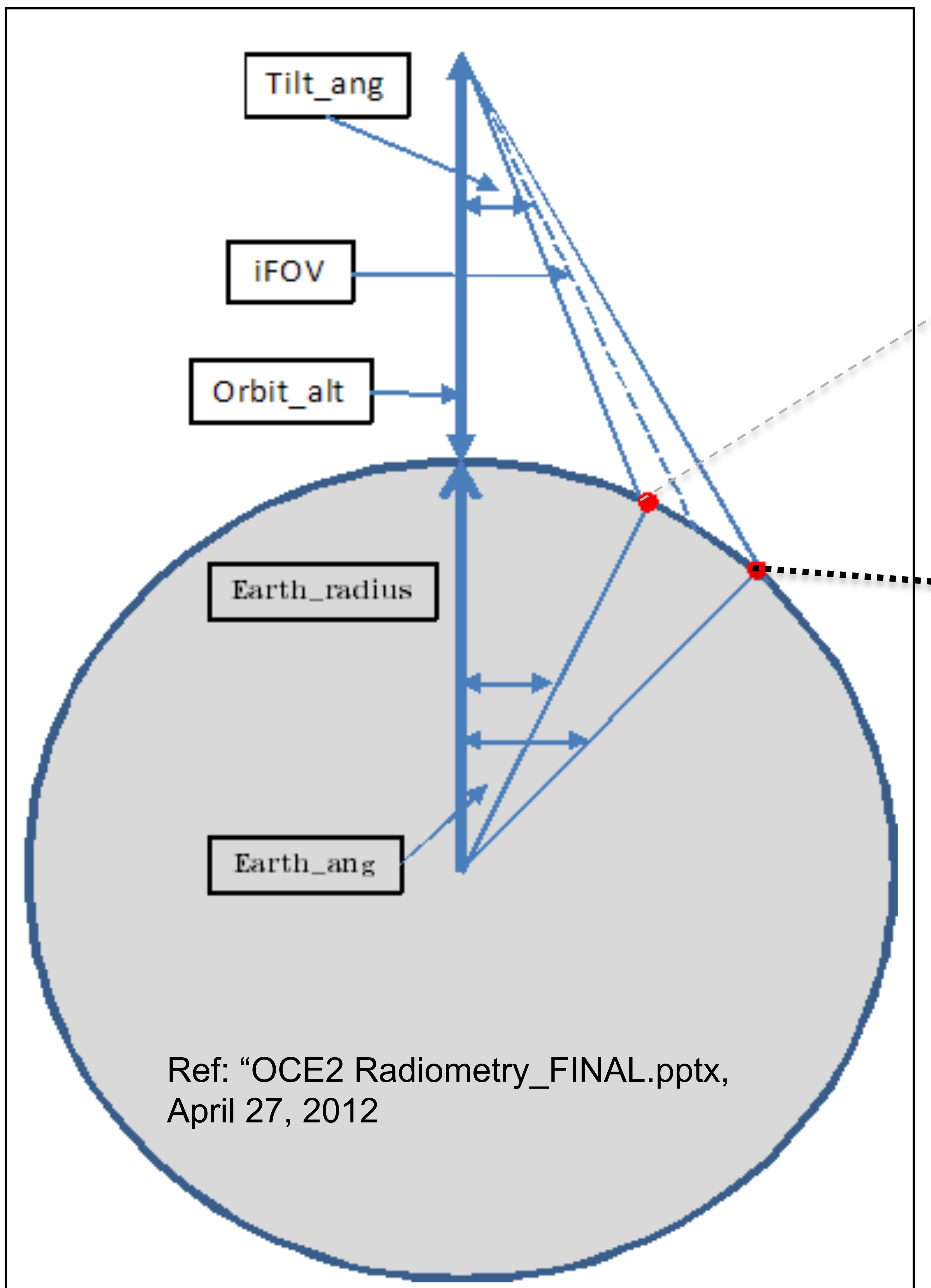
Instrument Accommodation

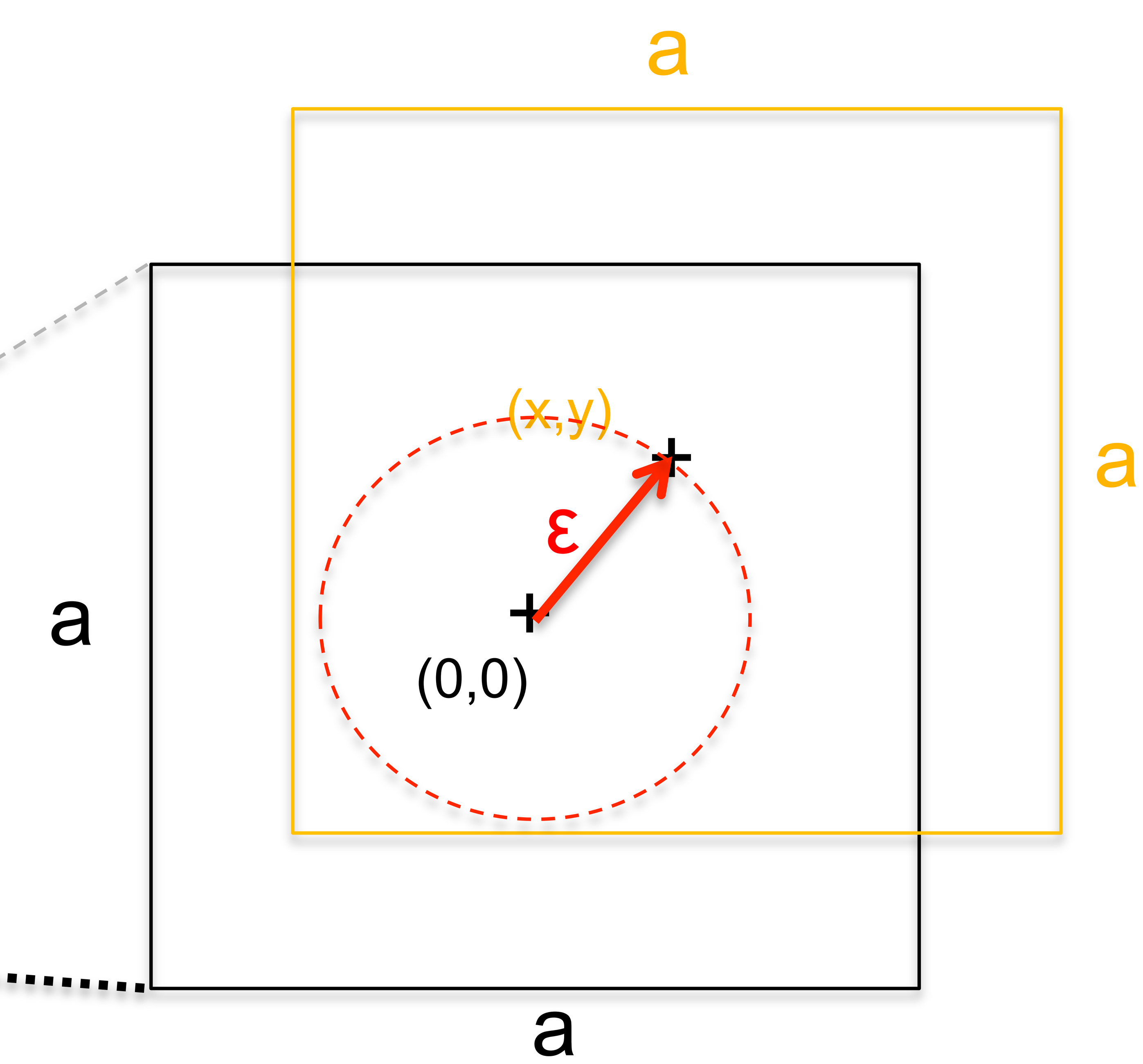
- **SCAN/IFOV**
  - **OCE2**: ± 51^{o} Crosstrack, 1.2328 mr (.07^{o})
  - **Polarimeter:** ±42.3^{o} along track, ±50.7^{o} crosstrack
- **Solar Avoidance**:
  - OCE & polarimeter: Avoid full sun on entrance aperture
- **Operating Requirements**
  - OCE & Polarimeter: On-orbit software uploads
- **Timing**
  - 1ms absolute
  - .1ms relative
- **Radiator (anti-sun side)**
  - **OCE:** Yes
  - **Polarimeter:** Yes
- **Data Interface**
  - **OCE:** Spacewire
  - **Polarimeter:** Spacewire

Instrument Accommodation

- **Contamination Control:**
  - **OCE:** UV Instrument Class Contamination Control Plan
    - Maintain clean dry purge
    - Bake out and materials program
    - Internal and external witness monitoring
    - Clean room/bench with molecular scrub system
    - Labyrinths vent ports, Volume purge rate studies
    - Instrument port cover or labyrinth?
    - On-orbit bake out before opening up instrument
- OCE Tilt Slew rate:
  - $+20^{o}$ to -20^{o} in 15 sec
- OCE Lunar Scan Rate
  - 60-90 sec to slew through moon: 1 deg/min. All detectors calibrated.

OCE Cumulative Pointing Error (CPE) Est.





- Requirement: 1 km^2 +/- .1 km
- ε ~ .1 km
- IFOV=1.2328 mr = 254.28 arcsec

CPE~ ε IFOV

- a=1km; CPE~25.4 arcsec
- a=.5 km; CPE~12.7 arcsec
- a=.25 km; CPE~6.4 arcsec

OCE2 – Data rate Summary

Fiber optic focal plane concept #1

Cumulative A/D output datarate

$$\frac{144}{30\mu s} = 4.8 \times MHz$$

Realtime Datarate - internal

$$\frac{144 \times AD\_bits}{30\mu s} = 67.2 \times M\_BPS$$

Avg. Datarate per Scan - to S/C bus

$$\frac{144 \times AD\_bits}{30\mu s} \times \left(\frac{Crosstrk\_scan}{360 \times deg}\right) \times Compression \times CCSDS\_overhead = 9.71 \times M\_BPS$$

Avg. Datarate per Orbit

$$\frac{144 \times AD\_bits}{30\mu s} \times \left(\frac{Crosstrk\_scan}{360 \times deg}\right) \times \left(\frac{Lat\_coverage}{360 \times deg}\right) \times Compression \times CCSDS\_overhead = 4.855 \times M\_BPS$$

Data Volume per Day

$$\frac{144 \times AD\_bits}{30\mu s} \times \left(\frac{Crosstrk\_scan}{360 \times deg}\right) \times \left(\frac{Lat\_coverage}{360 \times deg}\right) \times Compression \times CCSDS\_overhead \times 1day = 419.489 \times G\_Bits$$

$AD\_bits = 14$

$Compression := 0.5$

$CCSDS\_overhead := 1.02$

$Crosstrk\_scan = 102 \times deg$

2 day global repeat - +/- 51 deg.

$Lat\_coverage = 180 \times deg$

Sunlit + Lat_coverage - +/- 90 deg.

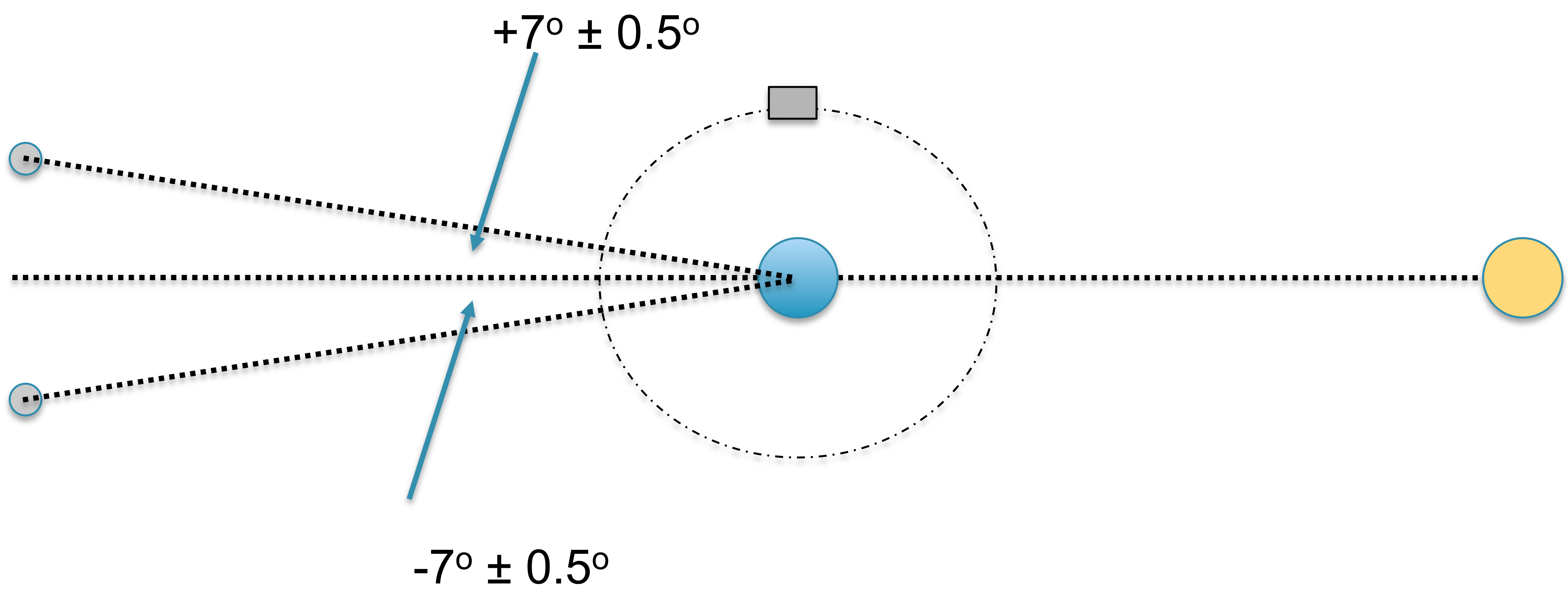
Concept Of Operations (CONOPs)

- Observatory Modes:
  - Normal Operations:
    - OCE Observing: 2-day or less global coverage,
      - +/- 20 deg. tilt operations twice per orbit for sun glint avoidance.
      - OCE buffers, compresses (2:1) and sends scan (but not the back-scan “in side of the can”) data to the SC.
    - Polarimeter Acquisition: 2-day coverage
    - OCE Solar calibration: Daily over poles
    - OCE Lunar calibration: Monthly, requires SC maneuver
    - Data Broadcast (Option): Real-time broadcast of all data.
    - Science Data Downlink: Observe while sending
    - OCE Standby mode: Same as observing mode for OCE. SC does not store or downlink OCE data.
    - Polarimeter Standby Mode: SC does not store or downlink Polarimeter data.
    - Safe Mode: Instrument off, SC provides thermal control. Avoid direct solar illumination of OCE aperture.
    - Launch Mode: Instruments off or standby, caging or launch lock.

Concept Of Operations (CONOPs)

- Observatory Modes (cont'd):
  - OCE Calibration Modes:
    - Monthly characterization: SC maneuver's so that OCE can observe the moon at $7^o \pm 0.5^o$ phase through the same OCE aperture and optics used for earth observation. For radiometric consistency, prefer either $+7^o$ or -7^o. (See next chart)
    - Daily/Weekly Solar Calibration: Solar illuminated internal test targets (at least three ; Nadir pointing - 0° tilt) at or near orbit terminator crossings to provide temporal tracking of radiometry and spectral drift sensitivity;
  - OCE & Polarimeter: Vicarious Earth based observations when opportunities arise.

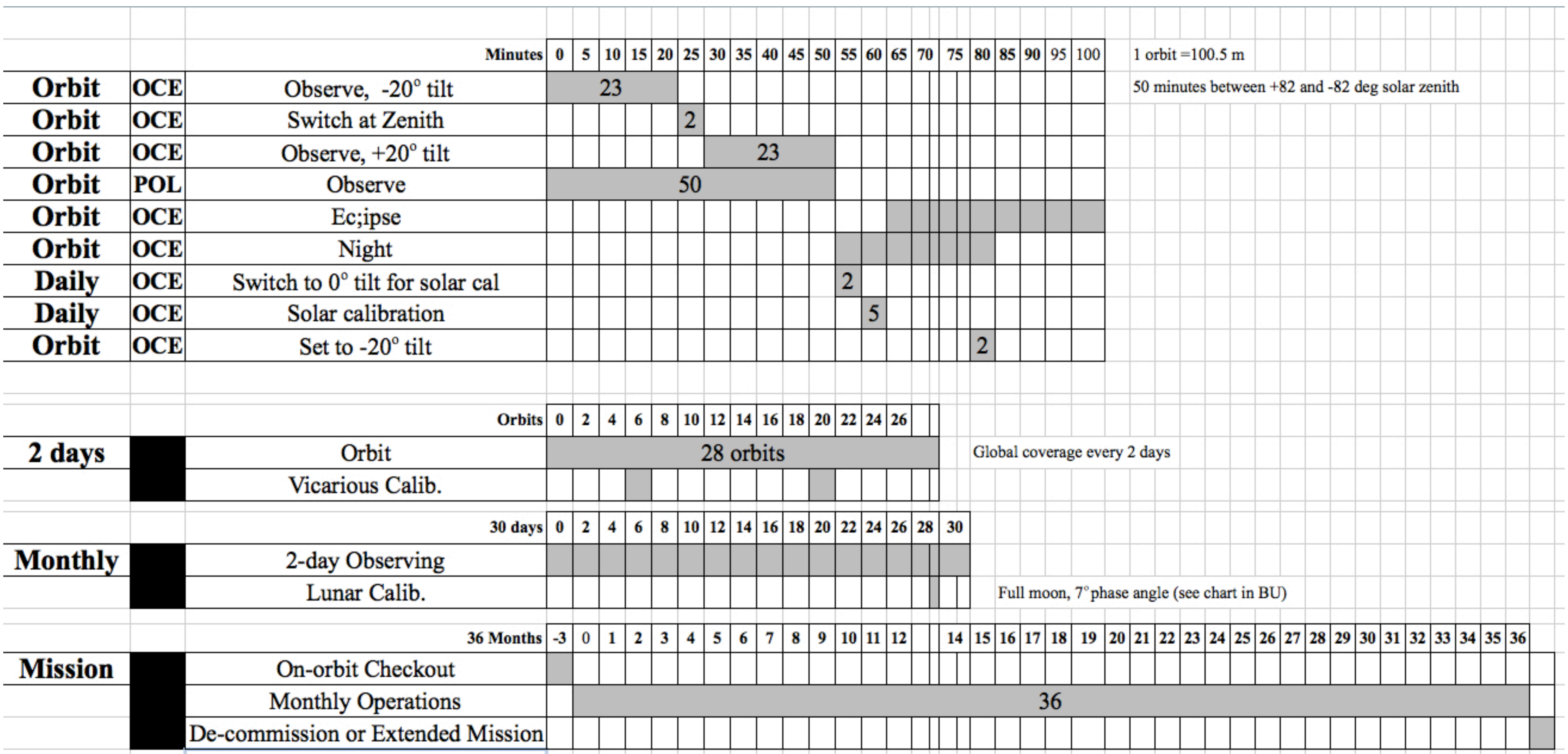
Lunar phase angle



Concept Of Operations (CONOPs)

- Communication:
  - Receiving ground service assumed for broadcast option: X-band
  - Assume 100% of full science data rate but assume 50% orbital DC (sun-lit portions only)
- Mission Operations:
  - Where should we assume MOC is located?
- Science Operations:
  - Where should we assume SOC is located?
  - Capacity for full reprocessing of PACE data at a minimum frequency of 1 – 2 times annually.
  - Data latency: 3 hours except for real time broadcast.

CONOPS: Notional Timeline



Key Questions & Trades

- OCE w Tilt Mechanism VS OCE wo Tilt Mechanism: SC provides anti-glare tilt
  - ±20 ±1^{o} tilt along track
  - Slew rate: TBD
  - Polarimeter that tilts?
- Real-time broadcast option
- Which RSDO Buses are viable?
- 1:30 pm equatorial crossing time? Thermal?
- Earth shield on OCE